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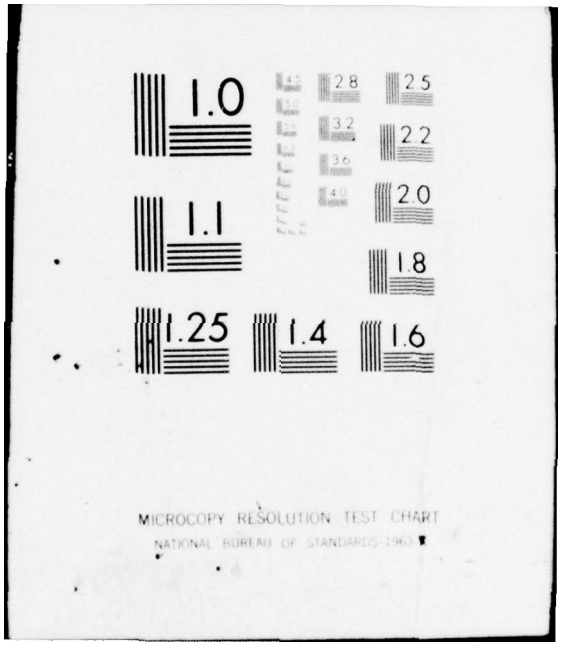
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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

TURNING AND MANEUVERING CHARACTERISTICS OF THE WMEC AS REPRESENTED BY MODEL 5347

by

Grant A. Rossignol

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SHIP PERFORMANCE DEPARTMENT

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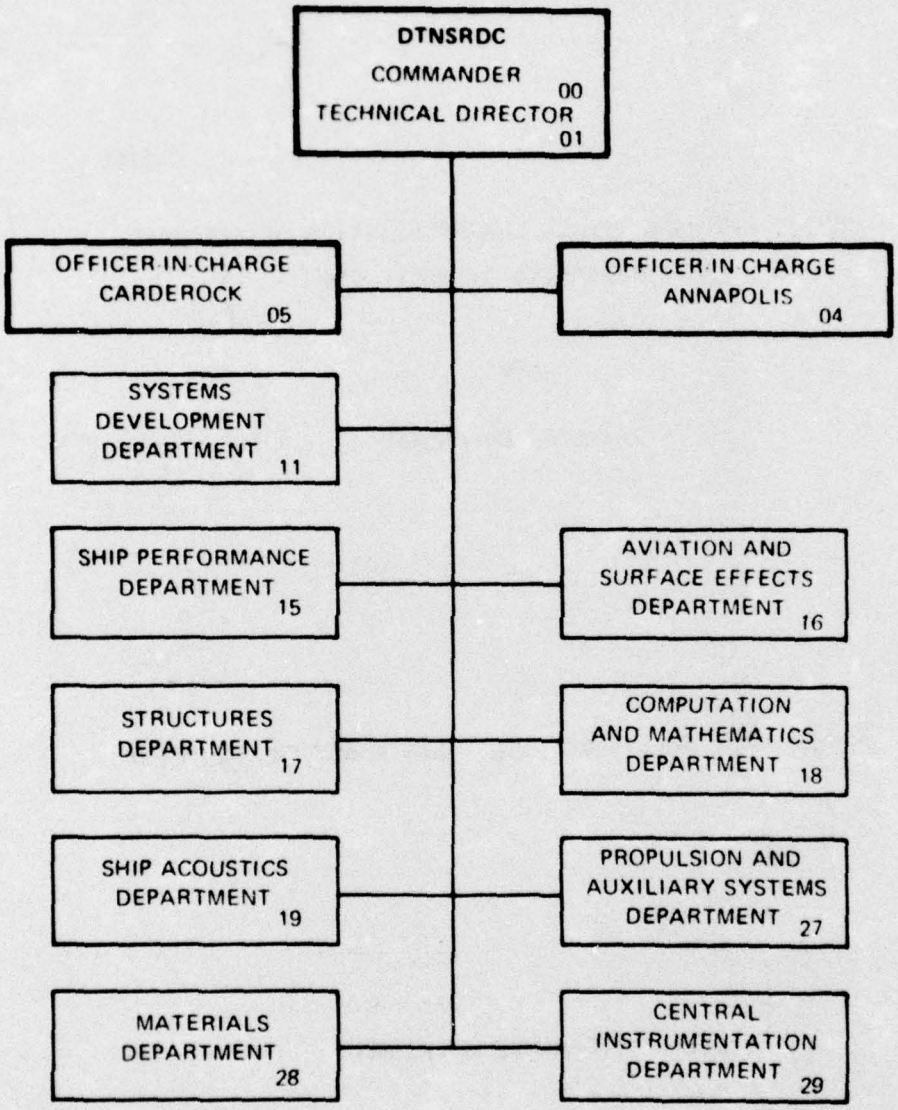

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The results of spiral and turning maneuvers conducted with Model 5347, representing a proposed design of the USCG Medium Endurance Cutter (WMEC), indicate that the ship will be directionally stable at an ahead speed of 5 knots and will have excellent turning characteristics, whether appended with the 69.6 square foot (6.47 square metres) rudders (A) or the 50.0 square foot (4.65 square metres) rudders (B). At an approach speed of 15 knots and a
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NOMENCLATURE

B	Maximum beam of ship
GM_T	Transverse metacentric height
L_{pp}	Length between perpendiculars
T	Draft
V_S	Ship approach speed
Δ	Displacement (weight) of ship
δ_r	Rudder angle
$\dot{\psi}$	Yaw rate

ABSTRACT

The results of spiral and turning maneuvers conducted with Model 5347, representing a proposed design of the USCG Medium Endurance Cutter (WMEC), indicate that the ship will be directionally stable at an ahead speed of 5 knots and will have excellent turning characteristics, whether appended with the 69.6 square foot (6.47 square metres) rudders (A) or the 50.0 square foot (4.65 square metres) rudders (B). At an approach speed of 15 knots and a rudder angle of 35 degrees, the ship will turn in 2.80 ship lengths when appended with the large rudders as compared to 3.53 ship lengths when appended with the small rudders.

ADMINISTRATIVE INFORMATION

This work was authorized by the Military Interdepartment Purchase Request Number Z-70099-6-62370. The work was performed under the David W. Taylor Naval Ship R&D Center (DTNSRDC) Work Unit Number 1-1568-022.

INTRODUCTION

The United States Coast Guard (USCG) requested DTNSRDC to conduct various experiments to assist in the development of design plans for the WMEC. This report contains the results of spiral and turning maneuvers.

Experiments with the free-running model were conducted in the David Taylor Model Basin. The spiral maneuvers were carried out at a ship approach speed of 5 knots, while the turns were made at speeds of 10, 15, and 20 knots. Two pairs of rudders of different sizes were used so that the size determination could be made.

DESCRIPTION OF PROTOTYPE AND MODEL

The principal characteristics of the ship and model are given in Table 1. The proposed design of the WMEC, as represented by Model 5347, has a length between perpendiculars of 225 feet (77.72 metres) and a displacement of 1762 long tons (1790 tonnes). The ship is steered by twin, spade rudders and propelled by twin, outward turning propellers. The model, shown in Figures 1 and 2, is a 1:14.439 scale version of the ship.

Center stock propellers 4507 and 4508 representing diameters of 9.0 feet (2.74 metres) and having four blades were selected for these experiments. Two pairs of rudders were used and designated A and B. The larger rudders (A) have areas of 69.6 square feet (6.47 square metres) each, while the smaller rudders (b) have areas of 50.0 square feet (4.65 square metres). The comparative sizes of these two pairs of rudders can be seen in Figure 3. Further details of the rudders can be seen in USCG Drawing: 270 Ft. WMEC Model Test Appendage Configuration of 26 May 1976.

EXPERIMENT PROCEDURE

The experiments were conducted with the model ballasted to the particulars given in Table 1. Time histories of yaw rate, rudder angle, and heel angle were measured by a rate gyro, rudder servo, and roll gyro, respectively. The signals from these transducers were recorded on Mosely strip chart recorders.

The spiral maneuvers were conducted for a ship speed of 5 knots using both pairs of rudders. Adequate data were obtained to ensure that a full evaluation of directional stability could be made.

The turning maneuvers were conducted in the J-basin with the path of the model being photographed by overhead cameras throughout the turn. In addition, visual observations of the distance between the release point on the towing carriage to the point where the model had changed 180 degrees from the base course were made and used to give an immediate estimate of tactical diameter. Turns were made at rudder angles of 20, 25, 30, and 35 degrees of ship approach

speeds of 10, 15, and 20 knots, using both pairs of rudders. Predictions of tactical diameter are made using the photographic plates. The turn at the 20-knot, 35-degree condition using the large rudders was not made because of the risk of model damage.

PRESENTATION OF RESULTS

The results of the spiral maneuvers are shown in Figure 4 as curves of steady yaw rate versus rudder angle for a ship approach speed of 5 knots. The data clearly show that the ship will be directionally stable using either pair of rudders at ship speeds of 5 knots.

Table 2 presents the estimates of tactical diameter and maximum heel angle which were obtained from the turning maneuvers. The tactical diameters are also presented in Figure 5 versus approach speed for various rudder angles and for both pairs of rudders.

The tactical diameter will vary from about 2.80 ship lengths at an approach speed of 10 knots and rudder angle of 35 degrees to about 4.92 ship lengths at an approach speed of 20 knots and rudder angle of 20 degrees when using the large rudders (A). When using the small rudders (B), the tactical diameter will vary from about 3.54 ship lengths at the 10-knot, 35-degree turn to about 5.20 ship lengths at the 20-knot, 20-degree turn. The difference between the tactical diameters from turns using the two pairs of rudders was constant with increasing speed. However, as the maximum rudder execute angle was increased, the difference in tactical diameter due to rudder size increased greatly.

Due to the small transverse metacentric height (GM_T), a considerable amount of heel angle was expected during the turns. The maximum amount of heel ($\sim$20 degrees) occurred during the 20-knot, 30-degree turn using the larger rudders. Had we made the turn at a rudder angle of 35 degrees with these rudders at this speed, more than 20 degrees of heel angle would probably have been measured. The large expected heel angle was another reason for not attempting the 20-knot, 35-degree turn with rudders A. The combination of large heel angle and tight turning could have resulted in model or equipment

damage. There is no indication that any rudder breakdown (stall) will occur for the range of conditions for which the experiment was conducted.

The overall handling qualities of the model are quite good. As is the case with most twin-screw, twin-rudder ships, the neutral angle is zero degrees. This rudder angle could be set and the model would continue in a straight path with no tendency to wander. The turning ability of the model was the most significant maneuvering characteristic observed during the experiment. When the model was appended with the large rudders, turns could almost be completed in the width of the basin.

CONCLUSIONS

Based upon the results of the spiral and turning maneuvers, the following conclusions are drawn:

a. The ship will be directionally stable at an ahead speed of 5 knots.

b. The tactical diameter will vary from about 2.80 to 4.92 ship lengths over the ship speed and rudder angle ranges for which turns were made using the large rudders (A).

c. When appended with the small rudders (B), the ship will turn in about 3.54 to 5.20 ship lengths for the speed and rudder angle ranges for which turns were made.

d. At an approach speed of 15 knots and a rudder angle of 35 degrees, the ship will turn in 2.80 ship lengths when appended with the large rudders as compared to 3.53 ship lengths when appended with the small rudders.

e. The maximum heel angle measured during the turns is approximately 20 degrees, at a ship speed of 20 knots and a rudder angle of 30 degrees and using the large rudders.

f. There is no indication that any rudder breakdown (stall) will occur for the range of conditions for which the experiment was conducted.

TABLE 1 - PARTICULARS OF THE WMEC

Agency	USCG
Ship	WMEC
Model No.	5347
Model Propeller No.	4507, 4508
Linear Ratio	14.439

Particular	Ship	Model
L_{pp}, ft (m)	255.00 (77.72)	17.66 (5.38)
B, ft (m)	37.98 (11.58)	2.63 (0.80)
T, ft (m)	13.50 (4.11)	0.94 (0.29)
Δ, tons S.W. (tonnes), lbs. F.W. (kg)	1762.00 (1790.00)	1278.00 (579.66)
GM_T, ft (m)	2.18 (0.66)	0.15 (0.05)
Trim by bow, ft (m)	0.00	0.00
Number of Propellers	2	2
Propeller Diameters, ft (m)	9.00 (2.74)	0.62 (0.19)
Propeller Pitch, ft (m)	9.58 (2.92)	0.66 (0.20)
Number of Blades	4	4
Number of Rudders	2	2
Rudder Type	Spade	Spade
Rudder Turning Rate, deg/sec	3.50	13.30
Rudder Area (A), ft^2 (m^2)	69.60 (6.47)	0.33 (0.03)
Rudder Area (B), ft^2 (m^2)	50.00 (4.65)	0.24 (0.02)

TABLE 2 - SUMMARY OF TURNING MANEUVERS CONDUCTED WITH THE WMEC

Rudders	V_S knots	$V_S/\sqrt{L_{PP}}$	δ_r degrees	Tactical Diameter			Maximum Heel Angle degrees
				yards	metres	ship lengths	
A	10	0.626	20	383	350	4.50	3.8
			25	327	299	3.85	3.8
			30	274	251	3.22	3.3
			35	239	219	2.81	4.9
	15	0.939	20	387	354	4.56	6.6
			25	326	298	3.84	6.9
			30	276	252	3.25	7.0
			35	238	218	2.80	8.1
	20	1.252	20	418	382	4.92	10.3
			25	347	317	4.08	17.0
			30	292	267	3.43	20.2
B	10	0.626	20	404	369	4.75	-
			25	339	310	3.99	-
			30	—	—	—	-
			35	301	275	3.54	-
	15	0.939	20	406	371	4.78	-
			25	337	308	3.97	-
			30	303	277	3.56	-
			35	300	274	3.53	-
	20	1.252	20	442	404	5.20	-
			25	362	331	4.26	-
			30	325	297	3.82	-
			35	310	283	3.64	-

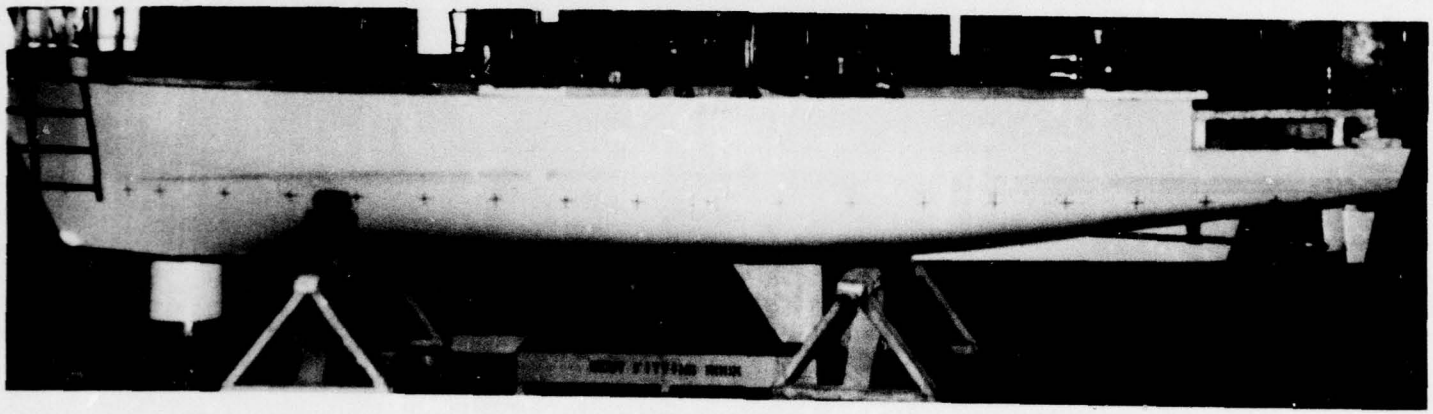

Figure 1 - Photograph Showing Port View of Model 5347

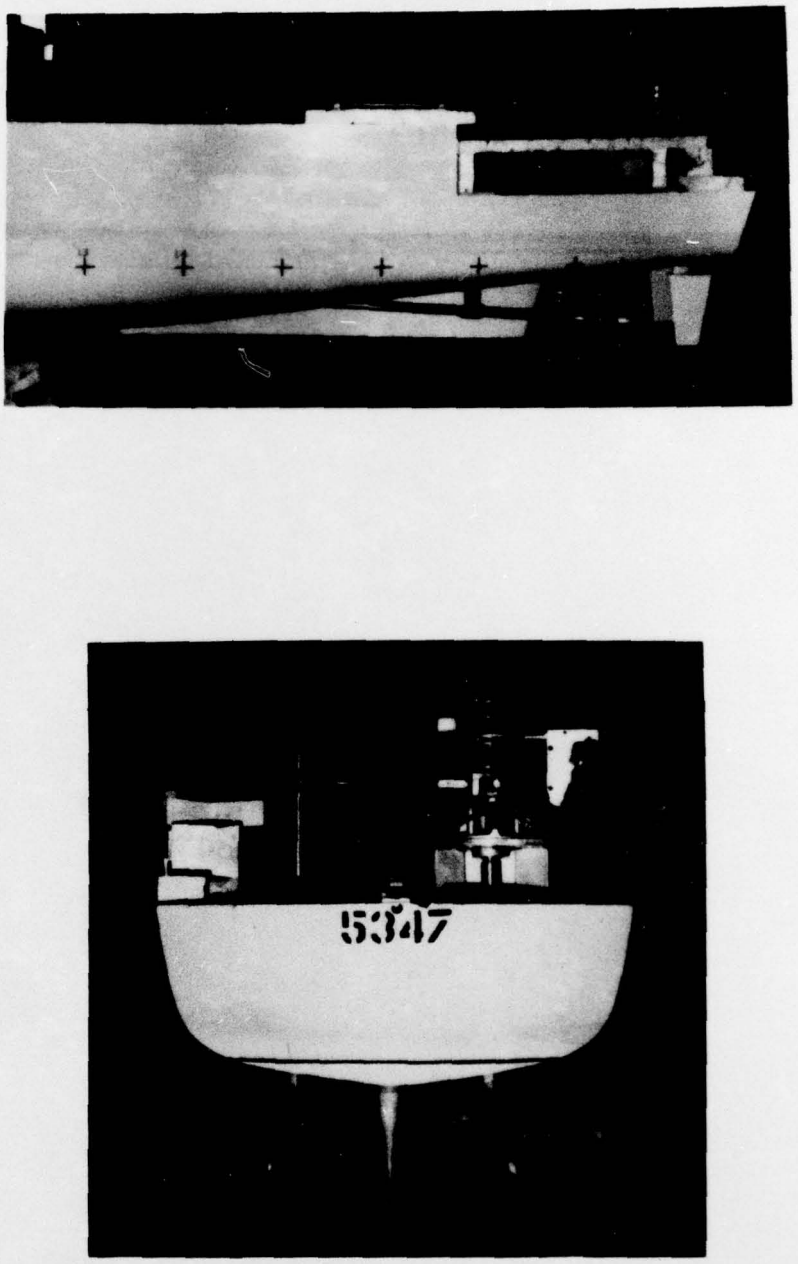

Figure 2 - Photographs Showing Port Profile and Transverse Views of the Stern of Model 5347

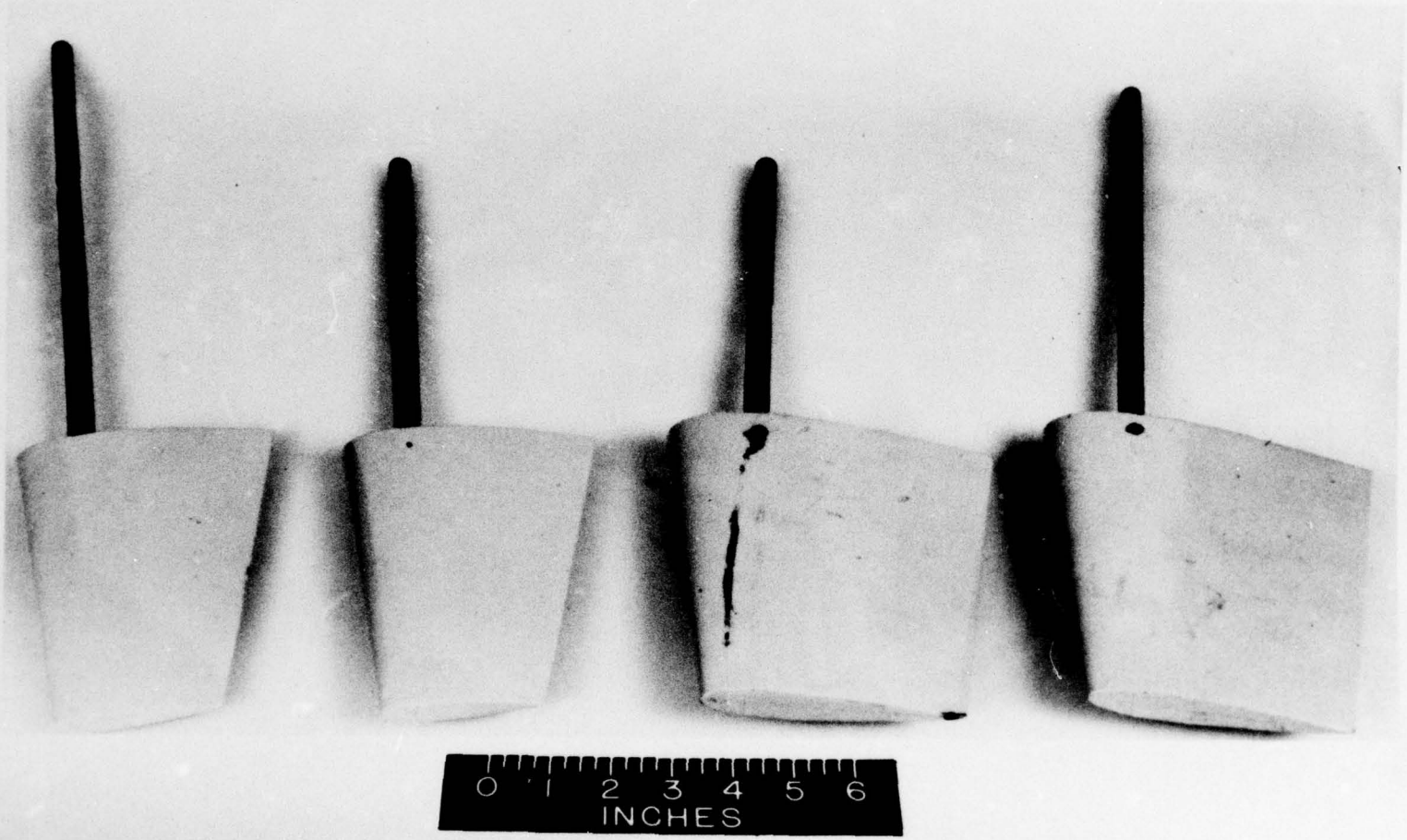

Figure 3 - Photograph of the Two Pairs of Rudders Used During the Experiment

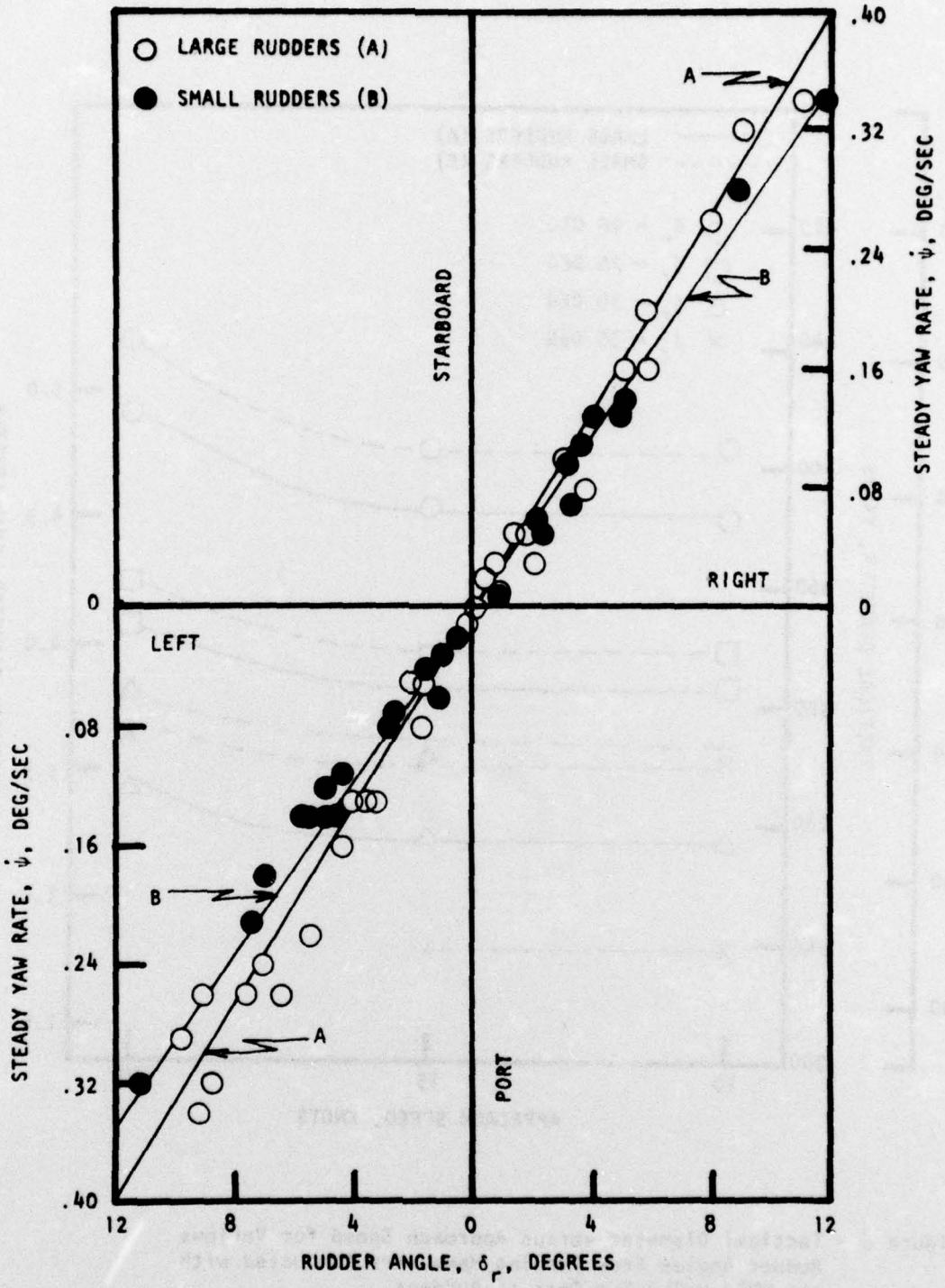

Figure 4 - Steady Yaw Rate versus Rudder Angle from Spiral Maneuvers Conducted with the WMEC at a Ship Speed of 5 Knots with Two Sets of Rudders

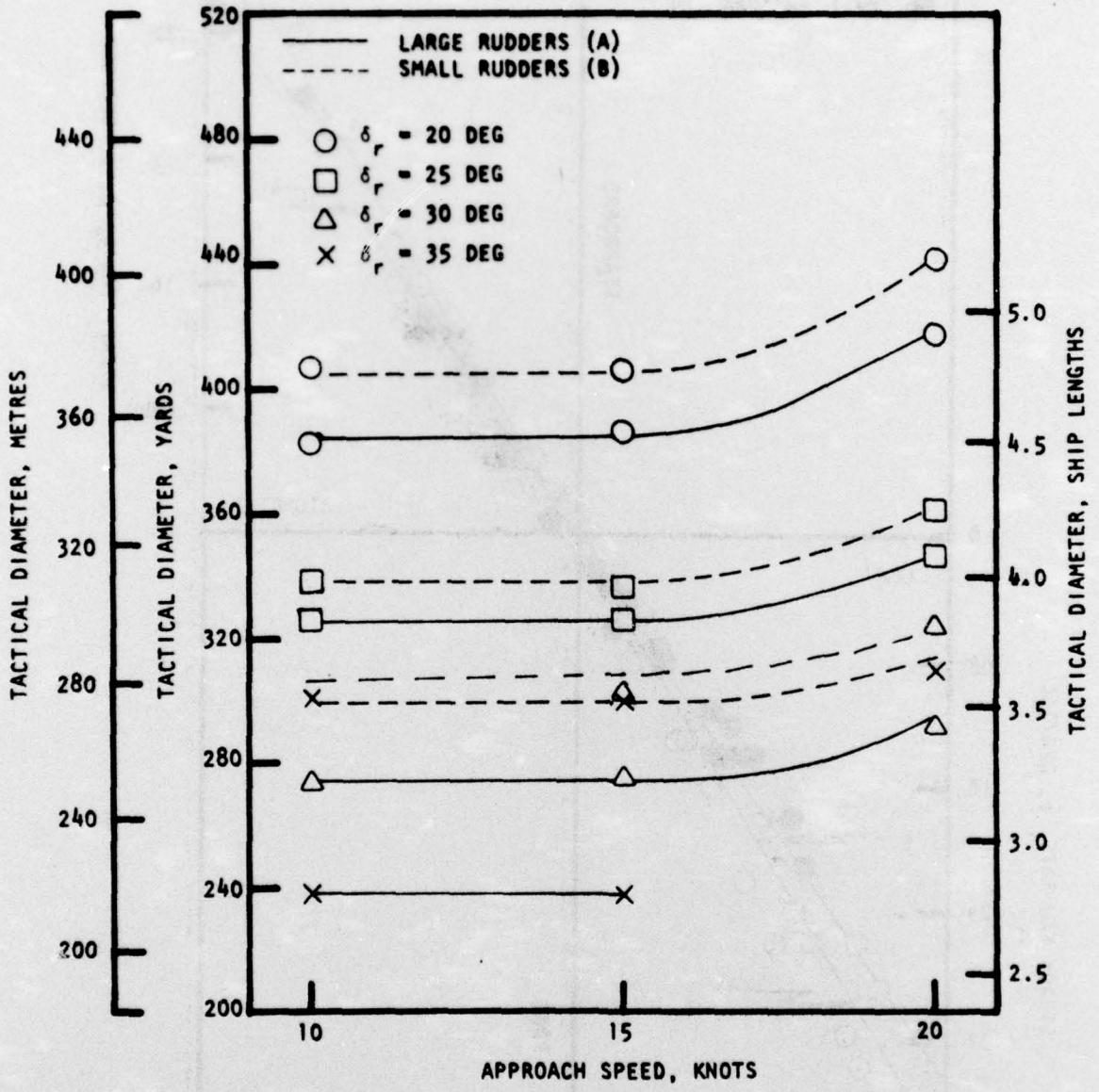

Figure 5 - Tactical Diameter versus Approach Speed for Various Rudder Angles from Turning Maneuvers Conducted with the WMEC Using Two Sets of Rudders

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